Government Office for Science

Foresight

Foresight Project on

Global Food and Farming Futures

Regional case study: R7

Agricultural production potentials in Eastern Europe up to 2050 in the context of climate change

Gloria Solano and Siemen van Berkum

LEI Wageningen UR

This review has been commissioned as part of the UK Government's Foresight Project on Global Food and Farming Futures. The views expressed do not represent the policy of any Government or organisation.

Contents

1 Introduction

According to its website[1], the Foresight Project on Global Food and Farming Futures addresses the issues of 'How can a future global population of nine billion people all be fed healthily and sustainably?' The project takes a global view of the food system; considering issues of demand, production and supply as well as broader environmental issues with a time horizon of 2050. The research focus of this study is on a particular region, namely Eastern Europe and investigates the question 'What is the agricultural production potential in East European countries out to 2050 in the context of climate change'?

The approach followed is a review of the existing literature and projections focusing on land use changes and agricultural production in Eastern Europe. This review considers briefly studies that do not assess the impact of climate change on agricultural production potentials. Next, the report reviews studies analysing the impact of climate change on agriculture. Until now, there has been little literature available on agricultural projections with the timescale considered here: the review refers largely to studies covering a time period up to 2020. Literature reflecting on the impact of climate change, though, takes a more long-term perspective; most of the recent studies on climate change cover a period up to 2070 or 2080. Most of these studies address the physical impact of climate change in agriculture and only few of them investigate the economic impacts.

This report focuses on Eastern Europe, a region that is defined as the part of Europe that used to be divided from the Western part by the Iron Curtain until the Berlin Wall fell in 1989. Hence, it includes all new member states of the European Union that joined since 2004; the former Yugoslavian republics, Ukraine, Belarus and Russia. However, as this is a literature review we follow the definitions and coverage of the countries found in that literature. Where necessary, we indicate the region and countries included more specifically.

---

[1] www.foresight.gov.uk

The report is structured as follows. In Section 2 we present agricultural projections of a number of recent studies and outlooks, which do not refer to impacts of climate change on the agricultural sector. In Section 3 we present an overview of studies that focus on the impact of climate change on agricultural production potentials, most specifically in the East European region. Section 4 presents conclusions.

2 Projections on agricultural production in Eastern Europe

2.1 Introduction

In this chapter we present some key features of present land use and yields, as well as an indication of what yields might be possible in the region of investigation. Furthermore, we review results of three recent agricultural outlook studies on future land use and agricultural production, indicating what production levels are possible under certain conditions. Two of the studies cover the middle term perspective until 2020 and one covers the long-term perspective until 2050. All three studies do not take into account any assumable effect of climate change on agricultural production.

2.2 Present land use and some indications of potential yields

Eastern Europe, defined by FAOSTAT as EU12, former Yugoslavia, Albania, the Russian Federation, Belarus and Ukraine, has an agricultural area of 332 million hectares (see Table 1). This is more than twice the area in EU15. About 80% of the agricultural area in the East European region is found in the Russian Federation, indicating the dominance of this country in the region. Ukraine and Belarus have an agricultural area as big as the area in the new member countries – EU12. Within the latter, the countries Poland and Romania account by far for the largest agricultural area. In the whole region arable land is dominant, taking two-thirds to three-quarters of agricultural land.

Table 1: Areas in Eastern Europe and EU27 (1000 ha)

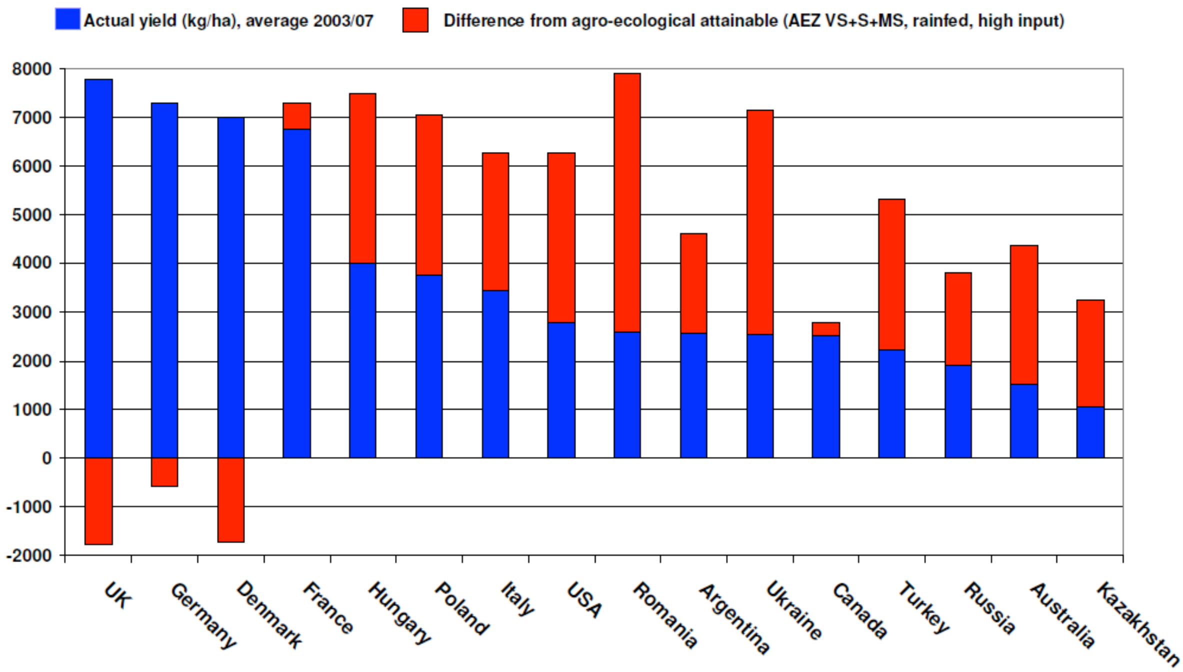
	Land area	Agricultural area	Arable land and Permanent crops	Arable land	Permanent crops	Permanent meadows and pastures
EU12	105698	53836	39258	37534	1724	14578
Russian Federation	1638139	215680	123581	121781	1800	92099
Ukraine	57938	41304	33353	32452	901	7951
Belarus	20748	8860	5571	5455	116	3289
ex-Yugoslavia +Albania	23455	12797	7457	6759	698	5340
Total Eastern Europe	1845978	332477	209220	203981	5239	123257
EU neighbours	1716825	265844	162505	159688	2817	103339
EU27	418687	192154	123083	110594	12489	69071

Source: FAO (2010), FAOSTAT data (2005)

Production per hectare differs widely between the countries in this region. Average wheat yields in Romania and Ukraine have been approximately 2.5 t/ha in recent years, while those in Poland and Hungary have reached about 4.0 t/ha. The average yield in Russia is below 2 t/ha (FAO Agrostat).

Figure 1 shows agro-ecologically attainable national average wheat yields for some selected countries and compares them with actual prevailing yields. Again note the wide differences of attainable average yields in these countries ranging from over 7 t/ha in Hungary, Romania and Ukraine to less than 4 t/ha in Russia. What is also clear is that there is a significant agronomic potential not yet used. Factors other than agro-ecology are responsible for the yield gap in relation to the agronomic potential. Such factors are the socio-economic and policy environments, which hamper farmers from adopting improved technologies and practices and make the best possible and most efficient use of inputs for producing crops that are most profitable. Yield growth requires policy changes that favour the socioeconomic environment, but also needs huge efforts to invest in technology adoption and development, physical infrastructure and market institutions. These all are long-term developments.

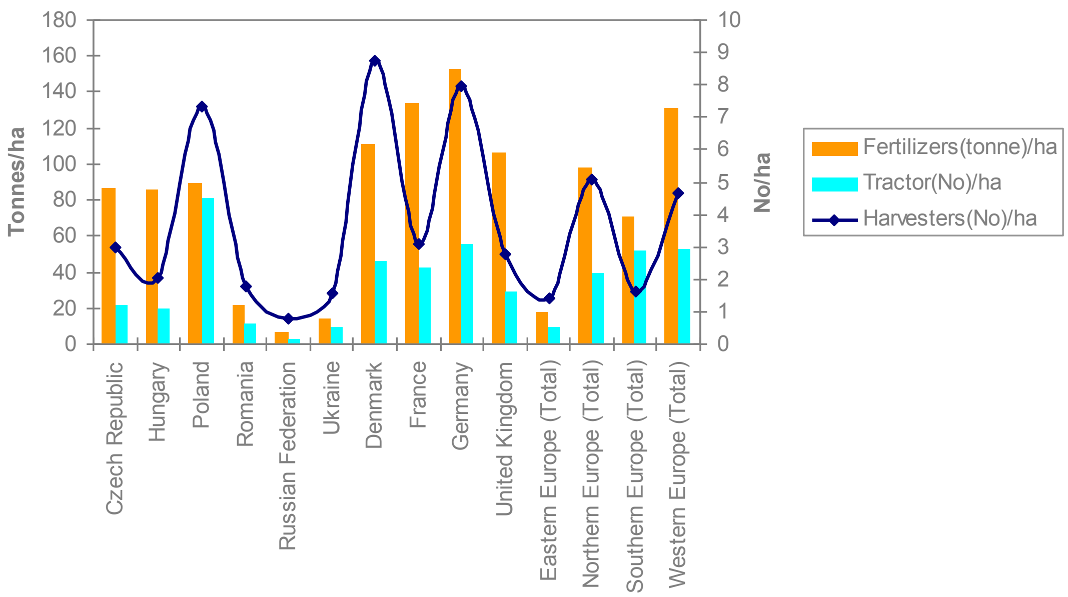
Figure 1: Actual and agro-ecologically attainable yields for wheat in selected countries



Source: Bruinsma (2009:28), data Fischer (2009) and FAOSTAT, cited by Bruinsma (2009).Note: AEZ: Agro-Ecological Zones; VS: very suitable (land); S: Suitable; MS: Moderately Suitable

Among the major wheat producers, only the EU countries in western and northern Europe, the United Kingdom, Denmark, France, Germany, have actual yields close to, or even higher than those attainable under rain fed high-input farming. In all other major producers, i.e. Eastern European countries (see Figure 1) with predominantly rain fed wheat production, the gaps between actual and attainable yields are significant. Even assuming that only half of their yield gap (attainable minus actual) could be achieved, their collective production could increase considerably without any increase in their area under wheat. Following the analyses on the input side of the agricultural production provides some insights into the reasons for the larger differences between actual and attainable yields in Western and Northern Europe, and Eastern Europe.

Figure 2: Fertiliser input, number of tractors and harvesters for selected countries and European regions



Source: FAOSTAT, 2010, data 2002

The data presented in Figure 2 indicate that whereas Northern and Western European farmers are resource intensive, farmers in Eastern Europe use considerably lower levels of fertilisers, tractors and harvesters per hectare. This implies that in Eastern Europe a resource extensive agriculture is the most widespread practice. The large differences between actual and attainable yields in Eastern European countries can at least partly be explained by the lower levels of resource use compared to Northern and

Western European countries. Poland is an exception to this. Further investment in fertilisers, machinery and other inputs appears to be necessary for achieving the attainable yields in East European countries.

2.3 Review of scenario studies on agriculture with no reference to climate change scenarios

The previous section indicates that in many East European countries production per hectare achievable is much higher than the actual production. This indicates that what is possible in a technical sense is not economically feasible. Will this be the case in the future? Will market developments induce a more resource intensive and higher productive production system in Eastern Europe? This section and the following chapter look into studies projecting agricultural production levels under different policy, socio-economic or climate change scenarios related to agriculture and trade. Such studies indicate to what extent the assumed attainable yields could be reached given the scenario story lines and assumptions of those studies.

For analytical purposes we divide the scenario studies into two groups: those who do not assess the possible impact of climate change on agriculture and those who do. Studies reviewed in this section do not take into account the possible impact of climate change on agricultural potentials. All three studies discussed assume yield improvements affected by technology developments according to trends in cost-saving technical progress.

The Scenar 2020-II study (Nowicki *et al.,* 2010) is an update of the original study carried out in 2006 aimed at identifying trends and driving forces that shape the European agricultural and rural economy up to 2020. The Scenar 2020-II presents results and analysis for the EU15 and the EU12, therefore countries like Ukraine, Belarus and the Russian Federation are not included. The update was necessary, as in this period the policy environment regarding the Common Agricultural Policy (CAP), bilateral and global discussions on trade of agricultural commodities and community objectives for the natural environment (including climate change mitigation) has experienced significant developments.

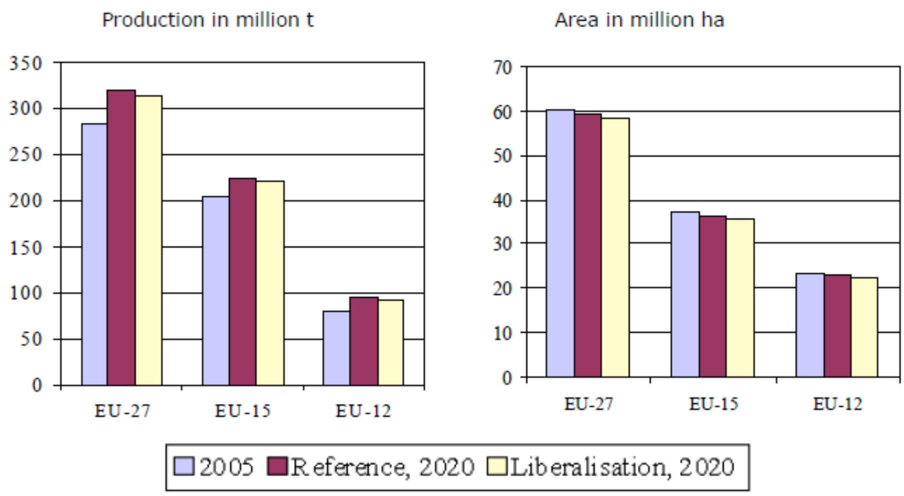
The Health Check 2008 is a review of the mid-term review of the CAP in 2003 which introduced new rules concerning agricultural payments in Pillar 1 (i.e. decoupling) and Pillar 2. From 2005, decoupling of financial support in Pillar 1 from production has been accompanied by the introduction of a compliance system which implies reduction of direct payments if standards and requirements on environment, food safety, animal welfare and good agricultural practices are not met. Also targeted payments of rural development (focusing on improving competitiveness or sustainable use of resources) can be mentioned.

The Scenar 2020-II presents an analysis of impacts inter alia, on agricultural production, farm income, number of farms and trade in different policy scenarios, covering EU27. The study considers three scenarios for the analysis: a reference scenario plus two policy scenarios, with the main features being:

- Reference scenario: incorporates the policy orientations that are associated with the 2008 Health Check, discussions related to the Doha Development Round (Falconer proposal of December 2008) and no enlargement of the EU beyond the existing EU27 is considered.
- Policy scenarios: the Conservative CAP scenario includes a flat rate (regional model) of direct payments at national level, and a lower rural development budget than in the reference scenario. The CAP liberalisation scenario excludes from all market intervention, direct payment support and import tariffs, yet with a similar rural development budget as in the reference scenario.

Results in terms of land use and production indicate that under the reference scenario cereal production in EU12 (the members since 2004) would expand by almost 20% (especially maize) between 2005 and 2020, while the total areas used for cereal production would decline by 1.4% in that period (see Figure 3). These outcomes confirm the findings of several studies on the impact of EU membership on the agricultural sector, indicating a positive effect of the introduction of the CAP and its support levels on agricultural production in most of the new member states in East Europe (www.agripolicy.net)[2]. Under the liberalisation scenario cereal production experienced a lower but still positive growth compared to the reference scenario, due mainly to the abolishment of direct payments and due to the reduction of trade policy measures. Under the liberalisation scenario total area used for cereal production declines slightly more than in the reference scenario compared to 2005.

Figure 3: Cereal production and land use under different scenarios, EU27, 2005-20



Source: ESIM results by Scenar 2020-II

Under the reference scenario oilseed production expands in the EU12 by more than 42% mainly explained by the increased biofuel production. Similar to cereals in the liberalisation scenario, oilseed production grows at a slower pace than in the reference scenario. The area used for oilseed crops in the EU12 increases by 7%, while the area in the EU15 is expected to decline. The strong expansion of oilseed area in the EU12 can be explained by the small initial share of oilseed area in the total area. As with the EU15, the EU12 experiences strong declines in the area used for other crops according to model projections.

---

[2] This website refers to a FP7 project in which a network of experts involved in agricultural policy analysis and rural development in the 12 New Member states and in eight candidate and potential candidate countries prepared reports on several relevant issues like the impact of direct payments on the agricultural sector in the 20 countries.

In the livestock sector, EU12 production of beef and pork declines under the reference scenario, while poultry production increases to some extent. However, the liberalisation scenario indicates a reduction in all meat producing sectors due to less market support (including trade protection). Milk and cheese production also declines in all three scenarios indicating that the region does not have a comparative advantage in livestock production.

The Scenar-II study highlights a number of structural changes in crop production patterns. On the one hand, crop production increases in all scenarios, but because of yield increases (reflecting technology improvement) the amount of land devoted to crop production can be expected to decrease. This process of reducing land use is emphasized under liberalisation scenario, since specialisation and economies of scale would accompany shifts in market shares based on relative prices in an open market. On the other hand, there are non-market determinants in crop demand, for example biofuel production mandated by the Renewable Energy Directive. Certain crops, which are also used for biofuel production, fare better under various future economic conditions than others; these 'biofuel crops' are a subset of arable crops that will have a differentiated market under liberalisation.

The OECD-FAO Agricultural Outlook 2010-2019 is a mid-term outlook and presents projections for the next ten years, following a baseline scenario assuming the continuation of policies, incorporating macroeconomic assumptions. The annual report focuses on main agricultural commodities and regions in the world. OECD countries are individually included in the model, except for those in the EU27, which is one entity in the model. There is no specification of Eastern Europe in the available data projections, yet the study does report projections for the Russian Federation (RF) and Ukraine.

Estimated annual growth rates of production indicate that the perspectives for oilseeds, beef & veal and poultry meat are promising in both countries. One should note, however, that in Russia the annual growth rates in the previous decade have been much higher for oilseeds and poultry meat. For beef and veal, the OECD counts on a remarkable recovery of production levels that have been steadily falling over the last two decades. Given the overall tendency that consumers prefer white meat (poultry meat and pork) over red meat, this estimation may be rather optimistic. OECD-FAO Outlook also foresees considerable growth of wheat production in the RF (see Table 2). Compared to the 2007-09 base period, agricultural production in RF and Ukraine are projected to growth of 26% and 29% up to 2019 (OECD-FAO 2010:15). Note also that the annual growth rates of pig meat and milk production in both countries are much below the world average, while growth rates of sugar production in the RF and wheat in Ukraine fall short of world averages. Oilseed production and poultry production showed a strong increase in the 2000-09 period as well as in the coming ten years, indicating the two countries' comparative advantage seems to lie in the production of these two commodities.

Table 2: Projections of production in average annual % change 2010-19

	Russian Federation	Ukraine	World
Wheat	2.43	0.79	1.10
Coarse grains	1.12	2.68	1.55
Oilseeds	2.65	5.11	1.90
Sugar	0.88	2.70	1.43
Beef & veal	2.73	3.57	1.51
Pig meat	1.75	0.78	1.75
Poultry meat	3.20	5.04	2.36
Sheep meat	1.96	3.01	2.12
Milk	1.54	1.32	2.18

Source: OECD-FAO (2010: Appendix B)

The OECD-FAO Outlook assumes that crop and livestock productivity continues to increase at long-term trend rates, at least in the most productive areas and that there is considerable potential for further increases over the next 10-20 years. The achievement of this potential widespread productivity increase requires the development and adoption of new technologies but growth in public agricultural research expenditure seems to be slowing. In many regions like Central and Eastern Europe, productivity can be significantly increased using existing technologies with better access to inputs, infrastructure development and extension services. The OECD-FAO study stresses that the Eastern and Central European countries have a long way to go to increase efficiency levels to match those of Northern Europe: not only does technical progress matter but access to it is important. Yield gains can not be achieved by technology alone, but also require necessary public and private investments and complementary changes in policies and institutions. On the other hand, the OECD-FAO wheat production projections for the next decade would imply a doubling of production in 30 years if this trend continues. If all production growth was the result of higher yields, production per hectare would double and meet the agro-ecological attainable yields as indicated in Figure 1.

The FAO 2006 report is a long-term study and addresses the global agricultural potentials up to 2050. It is a broad view of these potentials and does not focus in detail on what might happen in Eastern Europe as these countries are classified as Transition countries. This is a grouping of the EU's new member states, the Russian Federation and Ukraine and Central Asian countries. Nevertheless, we present the results of the FAO study for this group of countries and presume that the outcome for transition countries can be considered as illustrative of what we have defined as Eastern Europe in the introduction to this study.

The FAO study presents long-term estimations based on long-term historical developments. The report shows that world agriculture (aggregate value of production, all food and non-food crop and livestock commodities) has been growing at annual growth rates of 2.1-2.3% in the last four decades (1961-2001). Agricultural production in Transition countries, however, showed only

0.3% growth per annum over this whole period. The low performance is primarily due to the period 1991-2001 when production value declined by 3.1% p.a. Projections up to 2030 indicate an annual growth rate of only 0.5%, compared to a world average growth rate of 1.5%. FAO expects even lower growth rates for the two decades after 2030 in Transition countries: 0.2%, which is by far the lowest growth rate of all regions distinguished in the analysis (FAO, 2006, Table 4).

Table 3 presents the annual growth rates of some major commodity sectors. This overview indicates modest to low production growth of oil crops and cereals, while sugar production and milk/dairy production even declines in this group of countries. Bruinsma (2009) specifies FAO's approach in making the projections for land use and future yield levels. The author shows that all production increases achieved in the future are due to yield increases. Total arable land in use is 247 million ha in 2005 and the projection is that this area will decline by -10% to 223 million ha in 2050 (Bruinsma 2009:13). However, a continuous growth of cereals yields with 0.4% every year would imply a three times higher production per hectare in 20 years. For oilseeds the increase would be even higher. These yields may come close to what is attainable under present conditions already, but might fall short compared to future possible yields with new varieties introduced.

Table 3: Growth rates of agricultural production in Transition countries in average annual % change

	1999/2001-30	2030-50	1999/2001-50
Cereals	0.8	0.4	0.6
Milk and dairy products	0.1	-0.2	n.a.
Oil crops	1.5	1.3	n.a.
Sugar	0.0	-1.5	-0.6

Source: FAO (2006)

The three studies reviewed in this section point at good prospects for further production growth of major crops in the East European region. The medium term projections by the Scenar study indicate an increase of agricultural production of cereals (mainly maize), oilseeds and poultry meat in the EU12, while the OECD-FAO Outlook projects significant growth rates of these products in Russia and Ukraine too. Taking the long-term perspective, FAO projects an annual growth of agricultural production in the Transition countries at a modest 0.5% in the years up to 2030, declining to an average 0.2% in the period 2030-50. Oil crops and, to a lesser extent, cereals contribute to this increase.

As agricultural land use is projected to decline in all three studies, the production increase will be achieved by higher yields. Compared to present levels, estimated yield increases could result in significantly higher average production per hectare in 2050. However, as the OECD-FAO Outlook stresses, it would be a mistake to conclude that crop yields for major cereal, oilseed, and vegetable crops in all producing regions of the world will match those of the most productive regions or that the trend rate of increase in crop yields is the same everywhere. In Central and Eastern Europe, productivity can be significantly increased using existing technologies with better access to inputs, infrastructure development and extension services; there is still a long way to achieve potential attainable yield and productivity levels, which implies a large need for public and private investments, policy and institutional changes. Therefore it is not only internationally available technical progress that matters but access to it is also important.

3 Impact of climate change on agriculture in Eastern Europe

3.1 Introduction

This chapter explores in the literature the impact of climate change in Eastern Europe agriculture. Global warming is related to the increase of certain gases, mainly greenhouse gases (GHG) in the Earth's atmosphere. These produce a thermal blanketing effect that drives the temperature higher than it would be in their absence. However a change in temperature is not the only consequence of increased GHG emissions, as it will affect all aspects of the climate such as rainfall, wind directions and speed.

Agricultural production depends upon the dominant pattern of the weather and the impacts of climate change on agricultural production are geographically unevenly distributed. The major challenge of sustainable agriculture is to meet the food demand of the present generation without sacrificing the needs of next generations. To what extent societies will suffer economically from climate change depends on the magnitude and direction of the physical and biological impacts and the adaptive capabilities of the economy. The magnitude and direction of the impacts on agriculture will depend first on how the effects of climate change translate into factors that determine agricultural production potentials (physical impacts) including farm adaptation to altering climate conditions, and secondly on the adjustment abilities of the economy, which highly depend on socio-economic and technological conditions, and political processes (economic impacts).

The projected increase in GHG emissions and their higher concentration in the atmosphere is expected to affect agricultural production either directly (e.g. positive response of plant growth to higher CO_2 concentrations – CO_2 fertilisation) or indirectly via effects on climate change (e.g. higher temperature or rainfall changes). The effects of climate change can be positive in some regions and negative in other regions. The overall impacts of climate change on agriculture will depend on how the different expected positive and negative effects balance in different regions and the adaptation capabilities driven by socio-economic conditions and policies.

Our review focuses on studies which evaluate climate change impacts, biophysical and/or economic, including regional analysis containing the East European countries. The reader must be aware that the regional subdivision varies across the different studies and therefore results are not easily comparable.

There are studies addressing the assessment of biophysical impacts of climate change on agriculture at world and regional level. However, only few studies address the potential economic impacts of climate change on the agricultural sector in different geographical regions. Out of more than 30 reviewed studies[3], four studies quantify biophysical effects (including CO_2 fertilisation) and three studies quantify economic effects of climate change on agriculture covering East European countries. Most of these studies point out the need of analysing the climate change impacts from a long-term perspective and the time horizon considered in the studies varies from up to 2030, 2050 and 2080, with the last being the most frequently used in the different assessments.

This chapter is structured as follows. Section 3.2 presents some common features of approaches used by studies we have reviewed. In Section 3.3 the expected effects of climate change on agriculture in East European countries are described. First, changes in climate variables, according to projections of General Circulation Models (GCMs) in different socio-economic scenarios are shown. Second, the potential risks and opportunities for East European agriculture are described. Third, the projected biophysical changes are presented, followed by the agricultural projections without climate change (used as a reference) and the projected changes under climate change, with and without economic adjustments, and with and without adaptation to climate change. Results for some selected countries are also presented.

---

[3] Full list with references available upon request.

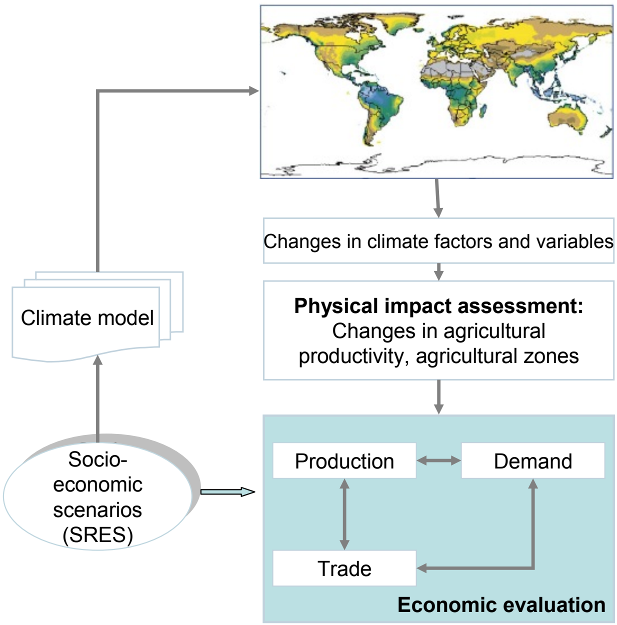
3.2 Features of studies on climate change impact on agriculture

3.2.1 General approach

Relevant studies for this review have used a variety of crop and economic models as well as diverse socio-economic scenarios and regional aggregation to assess the potential impact of climate change on agriculture. An even greater source of uncertainty of climate change analyses is the variation in climate variable estimates given by different climate models. For these reasons the results of the reviewed literature widely differ among the studies. However, the approaches followed also show similarities. Climate change is considered to be a consequence of greenhouse gases emissions and their atmospheric concentrations. The level of CO_2 depends on the level of economic activities (e.g. fossil fuel energy consumption) and therefore on the speed and level of economic growth. The historic and future CO_2 emissions obtained for different economic growth scenarios, mainly the socio-economic scenarios from the SRES (IPCC, 2007), are introduced in General Circulation Models (GCMs) which project regional changes in temperature, precipitation, sea-level rise and other climate variables. The changes in CO_2 concentrations and in climate variables are introduced in agro-ecological or process-crop models to estimate the physical impacts of climate change on agriculture, mainly crop-yield changes, while some studies also address changes in land suitability. The yield changes are used in economic models in order to evaluate how the economic system (i.e. agriculture) reacts and adjusts to climate change.

The following diagram describes the general approach.

Figure 4: Agro-economic analysis of the impact of climate change on agricultural systems



Source: Based on Fischer et al. (2002) and PESETA-Agriculture study (2009)

3.2.2 Climate models combined with socio-economic scenarios

The General Circulation Models (GCMs) most commonly used for the climate projections are the HadCM3 model, developed by the Hadley Centre for Climate Prediction and Research, and the ECHAM model, which is based on the weather forecast model of the European Centre for Medium Range Weather Forecasts (ECMWF) and modified by the Max Planck Institute for Meteorology and the German Climate Computing Centre (DKRZ) to make it suitable for climate forecasts[4]. The literature on climate change uses these models in combination with socioeconomic scenarios to project impact of climate change. The different socio-economic development pathways strongly affect emissions and consequently the extent and pace of resulting climate change, as well as the capacity to mitigate and adapt to climate change. The socio-economic scenarios used by the majority of recent studies are the scenarios described in the Special Report on Emission Scenarios (SRES)

---

[4] Detailed description of these two models as well as of some models also frequently used is available upon request.

from the Intergovernmental Panel on Climate Change (IPCC 2001 and 2007). These scenarios determine, on the one side, different levels of CO_2 emissions depending on the level of economic activity, being the different levels of CO_2 emissions that drive climate change. On the other hand, the SRES scenarios determine the socio-economic conditions for the future agricultural projections.

The following box presents a short description of the SRES scenarios.

Box 1: Socio-economic projections for constructing climate scenarios (SRES)

The IPCC was set up by the United Nations in 1998 to produce assessments of the state of the Earth's climate system. The current state of scientific knowledge regarding climate change and its impacts was published early in 2007.

The IPCC uses global climate models and emission scenarios to estimate future changes in climate patterns. The scenarios cover a wide range of the main driving forces of future greenhouse gas emissions. The climate models, which represent the atmosphere and the oceans, involve conversions of projected emissions into atmospheric greenhouse gas concentrations and then variations in climatic variables.

The basic emission scenarios or SRES (A1, A2, B1, B2) represent storylines about possible world developments in economic growth, population increases, global approaches to sustainability and other sociological, technological and economic variables that could influence greenhouse gas emission trends.

In the scenario family A, economic development is the priority, while in the scenario family B, environmental sustainability considerations are important.

The "1" and "2" scenario groups differ in their technological development path: faster and more diverse in "1", and slower and more regionally fragmented in "2". Each scenario is identified as having low (B1), medium-low (B2), medium-high (A1) and high emissions (A2).

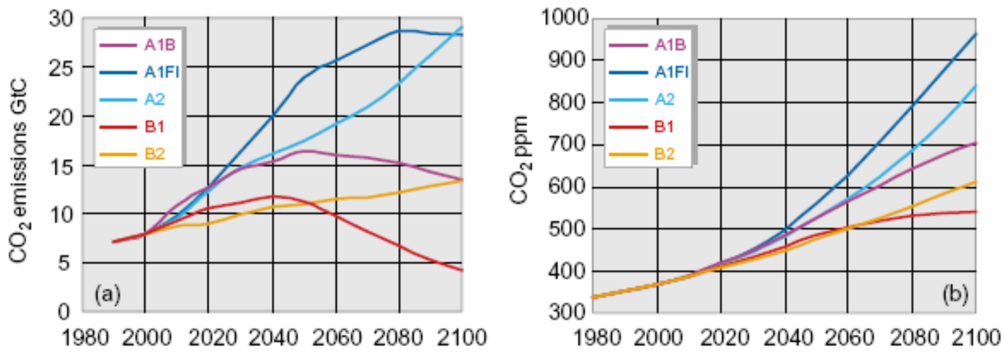
Table 1: Overview of main primary driving forces in 2020, 2050 and 2100 for the A1, A2, B1 and B2 scenarios

Scenario group	A1	A2	B1	B2
Population (billion) (1990 = 5.3)				
2020	7.6	8.2	7.6	7.6
2050	8.7	11.3	8.7	9.3
2100	7.0	15.1	7.0	10.4
World GDP (10 12 1990US$/ yr) (1990 = 21)				
2020	57	41	53	51
2050	187	82	136	110
2100	550	243	328	235
Per capita income ratio: developed countries and economies in transition (Kyoto Treaty Annex 1) to developed countries (Kyoto Treaty non-Annex 1) (1990 = 16.1)				
2020	6.2	9.4	8.4	7.7
2050	2.8	6.6	3.6	4.0
2100	1.6	4.2	1.8	3.0

Source: Adapted from the Special Report on Emission Scenarios by Iglesias et al. (2007)

Additional to the above described scenarios, Fischer *et al.* (2002) further developed scenario A1 into three groups that describe alternative directions of technological change in the energy system: fossil-intensive (A1FI), non-fossil energy sources (A1T), balance across all energy sources (A1B). Figure 5 illustrates the impact of such scenarios on CO_2 emissions and CO_2 concentrations in the atmosphere until 2100. The next figures show the wide variety of results.

Figure 5: IPCC SRES scenarios to 2100. (a) CO_2 emissions. (b) CO_2 concentrations



Source: Fischer et al. (2002)

3.2.3 Agro-biophysical models used for the assessment of climate change impact on agriculture

The next step in projecting the consequences of climate change for agriculture is to assess the biophysical effects of projected CO_2 emissions. The literature provides several approaches to evaluate biophysical impacts, mainly as yield responses (see PESETA study 2009 for an overview of methodological approaches used). Such yield responses are then used by other authors to introduce the results on productivity changes in their economic models over crop sectors in each region of the model. Studies in which biophysical and economic models are combined to assess climate impacts on agriculture and which include Eastern Europe are being used and reviewed in the following section. These are largely Olesen and Bindi (2002), Fischer *et al.* (2002), Deke (2001), Parry (2004), Parry *et al.* (2005), Alcamo *et al.* (2007) and the PESETA-Agriculture study (2009).

3.3 Impacts of climate change in agriculture in East European countries

3.3.1 Projected changes in climate variables relevant for agriculture production in East European countries

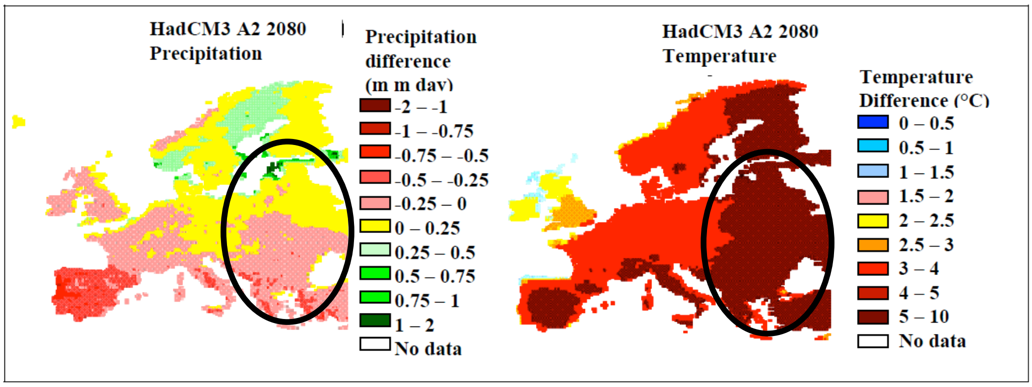
Climate change is expected to affect agriculture differently in different parts of the world. The variety of effects (from positive to negative) depends on the current climatic and soil conditions, the direction of the change in the climate variables and the availability of resources to adapt to and/or mitigate climate change. The differences across Europe are significant and these differences will influence the responsiveness to climate change. Most parts of Europe have experienced increases in surface temperature during the 20th century, with an European annual average mean of 0.8 ^{0}C. The results of the GCMs simulations indicate that the increase of atmospheric concentration of greenhouse gases might produce stronger climatic changes in future (Olesen and Bindi 2002). Agricultural production is directly affected by climate variables such as:

- Radiation: plant growth is based primarily on photosynthesis which is dependent on incoming radiation. The potential of agricultural production determined by radiation is largely modified by temperature and rainfall.
- Temperature: the main effect is to control the duration of the period when plant growth is possible in each year; also other processes linked with the accumulation of dry matter are directly impacted by temperature.
- Rainfall and soil water availability can affect the duration of the growth period by affecting the leaf area duration and the photosynthetic efficiency through stomatal closure.

The PESETA study (IPTS 2009) shows the changes in average temperature and precipitation resulting from running the GCMs HadCM3 and ECHAM, in the time horizon 2071-2100 compared to baseline 1961-90, and the ECHAM4 in the timeframe 2011-40 under the SRES socio-economic scenarios A2 and

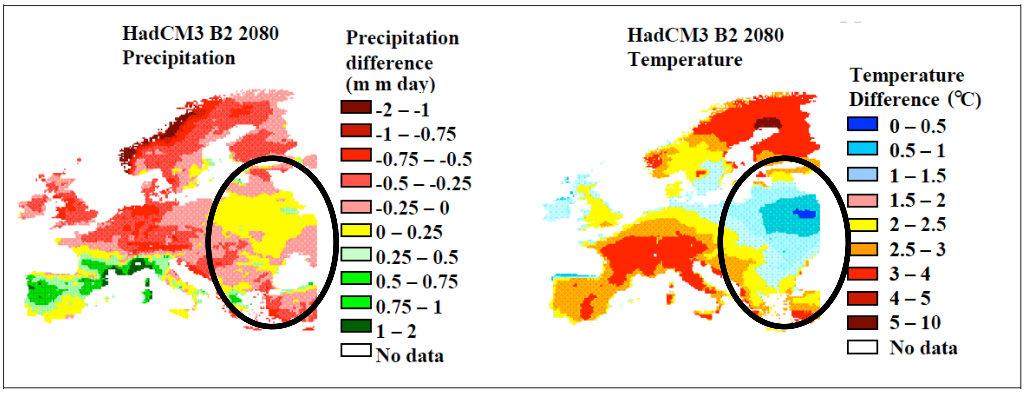
B2. Below in Figure 6 and Figure 7, results from the HadCM3 model runs are present for socio-economic scenarios A2 and B2.

Figure 6: Changes in annual mean temperature and precipitation by 2071-2100 compared to 1961-1990 (HadCM3-A2)



Source: PESETA-Agriculture (2009)

Figure 7: Changes in annual mean temperature and precipitation by 2071-2100 compared to 1961-90 (HadCM3-B2)



Source: PESETA-Agriculture (2009)

The HadCM3 projections according to the A2 scenario expect temperature increases in Eastern Europe countries between 3 and 4°C by 2080 or even 5 to 10°C for the countries situated more to the east. Precipitation is expected to increase between 0 and 0.25 mm day or even between 0.75 and 1 mm day in the northern areas, while East European countries situated in the centre or south are projected to experience precipitation decreases between -0.25 and 0 mm day. Using the scenario B2 the same climate model predicts much less dramatic temperature increases varying between 0 and 1.5 ^{o}C in the East European region. Precipitation would increase in the north-central countries by 0 to 0.25 mm day, while is projected to decrease in the north (Baltic) and in the southern countries between -0.5 and 0 mm day.

The ECHAM climate model projects stronger temperature changes than the HadCM3 model when taking the socio-economic assumptions of scenario A2. Temperatures would increase in most Eastern European countries between 5 and 10 ^{o}C by 2080, while the change in precipitation is more varied across the different countries. Countries situated in the north would experience increases between 0.25 and 0.75 mm day. Countries situated in the centre of Europe are projected also to experience some increases while in the countries in the south precipitation is expected to decline between -0.25 and -0.75 mm day. In the same scenarios but by 2040 we can observe that the changes are less dramatic.

Summarising the above leads us to the conclusion that under a scenario of rather slow technological development and high emissions (scenario A2) climate change would imply a 5-10 ^{o}C temperature rise in most of the areas of Eastern Europe, while precipitation is expected to increase in the northern areas and decrease in the southern areas of Eastern Europe. In case of significantly less CO_2 emissions (B2), temperature increases would be much less. This highlights the strong impact of different socio-economic scenarios on climate variables.

The climate model applied also affects the results, not only in terms of magnitude but also in terms of direction of effects. Fischer *et al.* (2002) shows results of simulating temperature and precipitation changes to different CO_2 concentrations using several climate models (General Circulation Models) for Eastern Europe, Russia and Central Asia. The next table summarises the changes in the climate variables, temperature and precipitation, in East European countries in 2050 and 2080.

Table 4: Responses of temperature to increasing CO_2 levels and changes in precipitation in Eastern Europe

	2050 Temperature increase in ^0C					2080 Temperature increase in ^0C				
	CO_2 emissions (ppm)	**HadCM3**	**CSIRO**	**CGCM2**	**NCAR**	**CO_2 emissions (ppm)**	**HadCM3**	**CSIRO**	**CGCM2**	**NCAR**
A1FI	550	3.5	3.4	3	1.7	800	6	6	5	3.2
A2	525	3.1	3.1	2.7	1.6	700	5	5	4.2	2.7
B1	475	2.4	2.4	2	1.4	525	3.1	3.1	2.7	1.6
B2	470	2.3	2.3	1.9	1.3	550	3.5	3.4	3	1.7
Change in precipitation		-‾	-	-‾	-		‾	‾	-‾	-‾

Source: own elaboration based on Fischer et al. (2002) data

Table 4 shows temperature increases with increasing CO_2 levels with all applied climate models. Results of changes in precipitation coming out from the different climate models are more diverse in East European countries (and Asia), while in Russia precipitation is expected to increase with increasing temperatures. These results illustrate that the predictions of changes in climate variables vary widely across the different climate models.

These differences in outcome in fact reflect the complexity of the processes that occur when the climate changes. There is consensus among the researchers in this field that elevated CO_2 concentrations in the atmosphere favour plant growth and a more efficient use of water resources (the CO_2. fertilisation effect)[5]. But higher CO_2 concentrations in the atmosphere imply also changes in climate variables such as temperature and precipitation pattern. The specifics of these changes in the different regions in the world and their impact on agricultural potentials together with socio-economic aspects that characterise the different regions determine the positive or negative impacts of climate change. The magnitude and direction of the impact of climate change on agriculture will depend on how the effects of climate change translate into factors that determine agricultural production potentials and on the possibilities of the economies to adapt to reduce the risks[6] (Iglesias *et al.,* 2007) and to implement measures to maximise the benefits and opportunities[7] of climate change (Fischer *et al.* 2002). Agriculture is very dependent on heat, sunlight and water as the main drivers of crop growth. On the one hand, the longer growing seasons and warmer temperatures are expected to bring some benefits, but on the other hand other impacts like reduced water availability or more frequent extreme weather events might have adverse effects on the agricultural sector. The different agro-climatic zones will face different impacts, risks and opportunities from climate change, but also different adaptation options because of different socio-economic and agronomic constrains as well as capacity for adaptation.

Iglesias *et al.* (2007) addresses the issues of risks and opportunities in their analyses of climate change effects on agriculture by categorising the opportunities and risks across the different European regions and assign to each risk or opportunity a value (High, Middle, Low) for the magnitude, likelihood and priority. East European countries are spread over four regional areas. Table 5 summarises the results of this analysis for only one of these areas, the Continental North zone.

---

[5] Recent results from the free air carbon dioxide enrichment (FACE) studies indicated growth increases of 10-25% for C3 crops (i.e. most crops) and 0-10% for C4 crops, such as maize and sorghum (Ainsworth and Long (2005); Long *et al.* (2004) cited by Alcamo *et al.* (2007).

[6] Risk is the possible adverse effect of a particular impact (e.g. summer droughts will reduce yields).

[7] Opportunity is the possible beneficial outcome of a particular impact (e.g. increased temperatures could expand potential areas for cultivation in Northern European regions).

Table 5: Risks and opportunities for the Continental North

Continental North zone	Detail of risk/ opportunity	Magnitude	Likelihood	Priority
Risk	Crop area changes due to decrease in optimal farming conditions	LOW	HIGH	MEDIUM
	Crop productivity decrease	LOW	HIGH	MEDIUM
	Increased risk of agricultural pests, diseases, weeds	HIGH	MEDIUM	HIGH
	Crop quality decrease	LOW	HIGH	MEDIUM
	Increased risk of floods	HIGH	HIGH	HIGH
	Increased risk of drought and water scarcity	HIGH	HIGH	HIGH
	Water quality deterioration	HIGH	MEDIUM	HIGH
	Deterioration of conditions for livestock production	MEDIUM	HIGH	HIGH
	Sea level rise	HIGH	HIGH	HIGH
Opportunity	Crop distribution changes leading to increase in optimal farming conditions	HIGH	MEDIUM	HIGH
	Crop productivity increase	MEDIUM	MEDIUM	MEDIUM
	Forest productivity increase	MEDIUM	LOW	LOW
	Water availability	HIGH	HIGH	HIGH
	Lower energy costs for glasshouses	LOW	HIGH	MEDIUM
	Improvement in livestock productivity	MEDIUM	HIGH	HIGH

Source: Iglesias et al. (2007)

The findings that follow from the study by Iglesias *et al.* (2007) for the whole of Eastern Europe indicate many opportunities for higher yields and increased production, but also point at the risk of water availability hampering farmers to make use of these opportunities. There are also some regional differences that should be noted. In the Continental North zone (which includes Poland, Lithuania, Latvia, Estonia, Czech Republic, Slovakia, northern Ukraine, Belarus) the increase in the northern range of crops and longer growing season offers the potential for increased crop and livestock production. However, water stress in summer and infertile soils may limit this potential. Flooding is a serious risk, too. Iglesias *et al.* recommends adaptation and mitigation priorities to be directed to reduce the risk of flooding and to conserve water to increase availability for agriculture. In the Continental South zone (Hungary, Romania, Serbia, Moldova, FYROM, southern Ukraine, and north-eastern Turkey) agriculture could be adversely affected by hotter drier summers with yields of crops such as potatoes, sugar beet and forage crops most likely to be reduced. Priority should be given to ensuring water supplies for agriculture and stimulating the growth of crops, such as soya, that could replace vulnerable crops. In the Alpine zone (Slovenia) changes in precipitation pattern and increased frequency of extreme events appear to be the greatest risks in this zone. There may be opportunities for increased production of both crops and livestock but the realisation of these opportunities will depend upon the continued availability of water at critical periods of crop growth. There may be benefits from a longer growing season and the possibility to grow some crops at greater altitudes, but this potential may not be realised due to soil limitations. In the Mediterranean North zone (Bulgaria, north-western Turkey, Croatia) the forecasted risks greatly outweigh any potential benefits. Forecasted decreases in total annual rainfall make water conservation a priority and careful attention needs to be given to avoiding potential conflicts over water use.

3.3.2 Biophysical impacts of climate change in East European countries

Within the literature, there is a significant number of studies addressing the quantification of percentage changes in crop-yields (in tons/ha) under climate change in a long-term perspective, but the number of studies is much reduced if we look for quantification of yield changes in Eastern Europe. Those studies available consider that changes in regional yields are the result of the interaction between temperature and precipitation effects, direct physiological effects of increased CO_2 concentrations and effectiveness and availability of adaptation. Still, due to the complexity of the biophysical processes the contribution of higher CO_2 concentrations to agricultural crop growth remains a crucial research question. For that reason, Parry *et al*. (2004) and IFPRI (2009) present in their analysis potential regional yield changes results with and without CO_2 direct effects. Although the SRES socio-economic scenarios are the most commonly used by the literature, as drivers for different levels of CO_2 emissions, not all studies select the same SRES scenarios to run their simulations. Moreover, the tools for assessing crop yield changes under climate change also vary among the studies. Parry *et al.* (2004) also points out that farm level adaptation is included with current technologies, which actually should be very different by 2080 and therefore the crop models applied in the analyses may underestimate the farm production potentials in the future. The literature also uses different climate models to assess the changes in the climate variables and therefore yield changes will strongly depend on the applied climate model. This all makes it difficult to give a concise and overall picture of the impacts of climate change on agriculture in Eastern Europe. The following is an attempt to do so.

Table 6 presents results on yield changes from several studies addressing changes in Eastern Europe including the positive effects of higher CO_2 concentrations (CO_2 fertilisation). Generally, yield decreases with temperature increases and increases with higher precipitation levels and higher CO_2 concentrations in the atmosphere are expected. The following results represent the overall effect of positive and negative consequences. The table shows potential changes in yields in the East European countries obtained from different studies under different socio-economic scenarios and climate models results.

Table 6: Estimated climate-change induced crop yield changes in East European countries

Climate model	Socio-economic scenario/ CO_2 levels	Regional area	Time horizon	PESETA - Agriculture 2009 (a)	Parry 2004/2005 (b)	Olesen 2002 (c)	Fischer 2002 (d)	Alcamo *et al.* (e)
HadCM3	A2	Continental North (Poland, Lithuania, Latvia, Estonia, Czech Republic, Slovakia, northern Ukraine, Belarus)	2080	1%	-2.5 to -5%			
HadCM3	A2	Continental South (Hungary, Romania, Serbia, Moldova, southern Ukraine, north eastern Turkey)	2080	26%	-2.5 to -5%			

Climate model	Socio-economic scenario/ CO_2 levels	Regional area	Time horizon	PESETA - Agriculture 2009 (a)	Parry 2004/2005 (b)	Olesen 2002 (c)	Fischer 2002 (d)	Alcamo *et al.* (e)
HadCM3	A2	Alpine (Slovenia)	2080	21%	-2.5 to -5%			
HadCM3	A2	Mediterranean North (Bulgaria, Croatia)	2080	-8%	-2.5 to -5%			
HadCM3	A2	Mediterranean North (North-western Turkey)	2080	-8%	5 to 10%			
HadCM3	A2	Russian Federation	2080		-2.5 to -5%			-10%
HadCM3	A2	European Russia	2070					-40 to -6%
HadCM3	A1F1	Eastern Europe	2080		-5 to -10%		-9%	
HadCM3	A1F1	Russian Federation	2080				6%	
HadCM3	B2	Continental North (Poland, Lithuania, Latvia, Estonia, Czech Republic, Slovakia, northern Ukraine, Belarus)	2080	4%	-5 to -10%			
HadCM3	B2	Continental South (Hungary, Romania, Serbia, Moldova, southern Ukraine, north eastern Turkey)	2080	11%	-5 to -10%			

Climate model	Socio-economic scenario/ CO_2 levels	Regional area	Time horizon	PESETA - Agriculture 2009 (a)	Parry 2004/2005 (b)	Olesen 2002 (c)	Fischer 2002 (d)	Alcamo *et al.* (e)
HadCM3	B2	Alpine (Slovenia)	2080	23%	-5 to -10%			
HadCM3	B2	Mediterranean North (Bulgaria, Croatia)	2080	0%	-5 to -10%			
HadCM3	B2	Mediterranean North (North-western Turkey)	2080	0%	2.5 to 5%			
HadCM3	B2	Russian Federation	2080		-5 to -10%			-12%
HadCM3	B2	European Russia	2070					-33 to +2%
HadCM3	S750 ppm (mitigated)	Romania, Ukraine and Bulgaria	2080		-2.5 to -5%			
HadCM3	S550 ppm (mitigated)	Romania, Ukraine and Bulgaria	2080		-2.5 to 0%			
ECHAM	A2	Continental North (Poland, Lithuania, Latvia, Estonia, Czech Republic, Slovakia, northern Ukraine, Belarus)	2080	-8%				
ECHAM	A2	Continental South (Hungary, Romania, Serbia, Moldova, southern	2080	33%				

Climate model	Socio-economic scenario/ CO_2 levels	Regional area	Time horizon	PESETA - Agriculture 2009 (a)	Parry 2004/2005 (b)	Olesen 2002 (c)	Fischer 2002 (d)	Alcamo *et al.* (e)
		Ukraine, north eastern Turkey)						
ECHAM	A2	Alpine (Slovenia)	2080	20%				
ECHAM	A2	Mediterranean North (Bulgaria, Croatia)	2080	-22%				
ECHAM	A2	Mediterranean North (North-western Turkey)	2080	-22%				
ECHAM	A2	Russian Federation	2080					-4%
ECHAM	A2	European Russia	2070					-40 to -3%
ECHAM	B2	Continental North (Poland, Lithuania, Latvia, Estonia, Czech Republic, Slovakia, northern Ukraine, Belarus)	2080	7%				
ECHAM	B2	Continental South (Hungary, Romania, Serbia, Moldova, southern Ukraine, north eastern Turkey)	2080	17%				
ECHAM	B2	Alpine	2080	-13%				

Climate model	Socio-economic scenario/ CO_2 levels	Regional area	Time horizon	PESETA - Agriculture 2009 (a)	Parry 2004/2005 (b)	Olesen 2002 (c)	Fischer 2002 (d)	Alcamo *et al.* (e)
		(Slovenia)						
ECHAM	B2	Mediterranean North (Bulgaria, Croatia)	2080	-2%				
ECHAM	B2	Mediterranean North (North-western Turkey)	2080	-2%				
ECHAM	B2	Russian Federation	2080					-5%
ECHAM	B2	European Russia	2070					-33 to 0%
Review of several models	Double CO_2 concentrations downscaled to 2050	Poland, Czech Republic, Slovakia)	2050			59%		
Review of several models	Double CO_2 concentrations downscaled to 2050	Rest East European countries incl. European part of former USSR countries	2050			3%		

(a) % changes in 2080 with climate changes with respect to potential under current climatic conditions (means 1961-90); winter wheat, spring wheat, rice, grassland, maize, soybeans; Simulations include private farmer adaptation in terms of changes in management to adjust to climate change; simulations considered no restrictions in water availability for irrigation due to changes in policy and did not include restrictions in the application of nitrogen fertiliser. Therefore should be considered optimistic from the production point and pessimistic from the environmental point of view; adaptation is explicitly considered and incorporated into the results by assessing country or regional potential for reaching optimal crop yield. Optimal yield is the potential yield given non-limiting water applications, fertiliser inputs, and management constraints. Adapted yields are calculated in each country or region as a fraction of the potential yield. That fraction is determined by the ratio of current yields to current yield potential; CO_2 positive effects are included.

(b) Projected climate induce-yield increases between 1990 and 2080; The data used to derive the production functions incorporated farm-level adaptation strategies, such as changes in planting date, and application of additional fertilisation and irrigation in the current irrigated areas. In addition, regional-scale adaptation is considered by modifying the yield changes derived from the production functions in developed countries to represent potential changes that require investments such as development of new cultivars and irrigation infrastructure; Adaptation that implies economic adjustments to the yield changes is tested by the BLS world food trade model which result in national and regional production changes and price responses; Economic adjustments represented by the BLS include: increased agricultural investment, re-allocation of agricultural resources according to economic returns (including crops witching), and reclamation of additional arable land as a response to higher cereal prices; The crop models include a number of simplifications. For example, weeds, diseases, and insect pests are assumed to be controlled; and there are no problem soil conditions (e.g. salinity or acidity); CO_2 positive effects are included. No estimate is made as to the negative effects of acid deposition and how this may affect yield levels. The complex and uncertain assessment of the contribution of the direct effects of CO_2 to agricultural crop remain a crucial research question. The crop models simulate the effect of drought conditions, but they do not respond to flooding (Rosenzweig *et al.* 1999). At the regional level, the functions may not represent the variability of agricultural systems within similar agro-ecological zones, or dissimilar agricultural regions. The farm-level adaptation included in the functions was derived from the crop models that simulate the current range of agricultural technologies available around the world, but by the 2080s agricultural technology is likely to be

very different and the models; Wheat, maize, rice and soybean. (c) Wheat, Maize, Sunflower, Soybean, Potato, Grapevine; CO_2 positive effects are included. (d) % changes in cereal production potentials compare to reference without climate change; Farming technology assumption used in this study High-level inputs/advanced management: Production is based on improved high yielding varieties, efficient combination of labour and mechanisation, uses optimum applications of nutrients and chemical pest, disease and weed control, and employs full conservation measures. The farming system is mainly market oriented; CO_2 positive impacts are included. Some of the interactions of temperature, moisture availability, and increased CO_2 on plant growth have been investigated through crop response models. These models have been widely used to assess yield response to climate change at many different sites around the world, and have produced valuable insights in these interactions (e.g. Rozema,1993; Rosenzweig and Parry 1994; IPCC 1996). There is generally agreement that an increase of atmospheric CO_2 levels leads to increased crop productivity. In experiments, C3 plants, such as wheat and soybeans, exhibit an increase in productivity of about 20-30% at doubled CO_2 concentrations. Response, however, depends on crop species as well as soil fertility conditions and other possible limiting factors. C4 plants, such as maize and sugarcane, show a much less pronounced response than the C3 crops, increasing productivity on average by 5-10%. In general, higher CO_2 concentrations also lead to improved water-use efficiency of both C3 and C4 plants (e) No CO_2 fertilisation effects are considered

Findings from the studies addressed in Table 6 are summarised below.

Although the projected results in the PESETA study are different for each climate model and emissions scenario, this study shows quite consistent spatial distributional effects. Northern Europe is projected to experience increases in crop suitability and productivity due to the lengthened growing season, decreasing cold effects in growth and extension of frost-free period. Southern Europe would experience crop productivity decreases caused by shortening of the growing period, with subsequent negative effects on grain production. The simulations consider farmers' adaptation but assume no restrictions in water availability for irrigation and do not include restrictions in nitrogen fertiliser application. Therefore, these projections might be considered optimistic from the agricultural production point of view. In Eastern Europe, we observe that while northern areas like Boreal (Latvia and Estonia), Continental North and South (Poland, Lithuania, Czech Republic, Slovakia, Ukraine, Belarus, Hungary, Romania, Serbia, Moldova, FYROM, north-eastern Turkey) will be mainly positively impacted by yield increases, the southern area called Mediterranean North (Bulgaria, north-western Turkey, Croatia) is expected to be negatively impacted by yield decreases in all scenarios and time horizons considered. The Boreal and Continental South zones show significant potential yield increases, while the potential yield increases in the Continental North zone are more moderate or even negative. The Alpine zone (Slovenia) presents positive crop yield changes except in the projections with time horizon 2011-40.

Parry *et al.* (2004) applied the HadCM3 climate model and took the SRES A2 and B2 socio-economic scenarios. The results of their analyses vary from -2.5% to -10% yield changes, which is much more pessimistic than the outcomes of the PESETA study. Parry *et al.* do not present further detailed regional analysis across Eastern Europe, but emphasise that their results are due to rather limited farm adaptation strategies, based on current available technologies. Relaxing this assumption would imply a much more positive impact of climate change on yields.

Fischer *et al.* (2002) shows projected changes for the socio-economic A1FI (fossil-intensive energy sources), which can be considered as a worst case scenario as resulting CO_2 emissions are much higher than in other scenarios. The estimated yield changes are -9% for East European countries which is consistent with the result estimated by Parry *et al.* in the A1FI scenario (-5% to -10%). The Fischer study also includes an impact assessment of climate change on suitable land for cereals. In Eastern Europe suitable land for cereals is projected to decrease by 4% in 2050 and 2080 compared to the reference period (1961-90). Together with the estimated reduction in yields this results in a significant climate change induced potential decline of cereal production in the East European region.

For the Russian Federation, Fischer estimates yield increases of 6% and a small increase of 1% of current cultivated land under cereals. These are outcomes for the whole country. Running different scenarios (than Fischer), Alcamo *et al.* (2007) projects negative impacts on yields for the Russian Federation, especially for the European part of it (see Table 7). However, contrasting with the other studies presented in Table 6, results from Alcamo *et al.* do not include positive impacts from the CO_2 fertilisation. Interestingly Alcamo *et al.* also shows that there are large differences across the regions within the Russian Federation and therefore the total result for the Russian Federation hides large regional differences between positive and negative impacts. Changes in temperature are expected to be 4-5% in the Northern regions and in Siberia up to 2070. As a result these regions show significant increases in cereal and potato production. Table 7 shows estimated changes in yields as percentage of current yields across different regions in the Russian Federation according to the HadCM3 climatic model.

Table 7: Future climate related potential crop production (HadCM3 climate model)

Economic region	A2 scenario				B2 scenario			
	2020s		2070s		2020s		2070s	
	Grain	Potato	Grain	Potato	Grain	Potato	Grain	Potato
Central	92	95	93	86	104	117	90	89
Central Chernozem	73	64	75	55	93	91	67	48
Far East	108	121	101	175	119	138	100	155
Kaliningradskaya	106	107	92	87	96	107	91	80
North	127	136	148	125	140	152	159	146
North Caucasus	82	72	60	38	73	62	65	49
North West	120	116	111	103	122	132	107	101
Ural	92	111	89	101	70	82	83	94
Volga-Vjatka	97	91	94	80	94	92	102	92
East Siberia	218	207	340	316	210	207	306	288
West Siberia	110	140	86	194	97	129	83	160
Povozhskey	76	—	77	—	71	—	76	—
Russia	94	106	90	104	91	122	88	104

Given as percentage of current mean potential crop production (average annual production from 1961 to 1990 = 100%). Grain production includes wheat and rye. Results based on climate scenarios from HADCM3 climate model.

Source: Alcamo et al. (2007)

Apart from the Russian study of Alcamo *et al.* (2007), we have come across a study on the impact of climate change on agriculture in Poland (Sadowski 2008). This study presents effects from climate change in agriculture in Poland until 2030. Although there are positive effects such as extension of the growth season and more favourable climatic conditions for corn, soybean and other oilseeds, Sadowski stresses that the negative impacts outweigh the positive. Major impact will be a reduction of potato yield by approx. 30% as a result of water deficit and the reduction of cereal yields by approx. 15% as a result of pests. According to this study the results will be a decrease of overall agriculture production of between 5% and 25% and significant inter-annual variation of yields.

3.3.3 Economic impacts of climate change in East European countries

The results on crop yield changes are used as input to derive economic impacts of climate change in the agricultural sector by using economic models that consider production, consumption, trade and policy options (see figure Figure 4). Results of projected changes in agricultural production, agricultural GDP or trade in East European countries up to 2050 can be found in Fischer *et al.* (2002), Tubiello and Fischer (2007) and the PESETA study (2009). Expected yield changes of Fischer *et al.* and the PESETA study have been described in the previous section. Tubiello and Fischer adds a new scenario which includes mitigation actions under the socio-economic scenario A2, which is then called A2r.

In order to estimate the economic impacts of climate change in agriculture, the estimated yield variations caused by climate change are introduced into the economic models by yield response functions. The yield changes computed with the agriculture models have mainly been interpreted as a productivity shock to the production side of the agriculture sector in the economy. Exogenous variables, such as population growth and technical progress, are left at the levels specified in the respective reference scenarios in the studies. No specific adjustment policies to modify performance of agriculture were assumed beyond the farm-level adaptations resulting from economic adjustments of the individual actors, except for the studies by Deke *et al.*

(2001) and Fischer *et al.* (2002), where the authors also compare agricultural projections under climate change with and without economic adjustments. These two studies find that the impacts of climate change are softened by the adjustments of the economy.

Fischer *et al.* (2002) compares cereal production and agricultural GDP under climate change scenarios in 2020, 2050 and 2080 with the projections under the same socio-economic scenarios with no-climate change. This study presents results as percentage changes between climate change projections and no-climate change projections in 2080. The Fischer study presents also results obtained with different climate models.

According to the Fischer projections with no-climate change cereal production is expected to increase in East European countries from 1990 to 2080 by between 52% and 93% in the B1 and A2 scenario respectively, while in the reviewed A2 scenario (A2r) cereal production is forecasted to increase by 85% (see Table 8). Compared to that increase, the impact of climate change on production levels would be positive according to all socio-economic scenarios and by all climate models used in this study. Next, Table 7 shows that the overall agricultural output in Eastern Europe is expected to decline according to two out of five results of the HadCM3 climate model, while other climate models project an increase.

Table 8: Cereal production projections under different scenarios and by using different climate models in EEU and FSU

		Reference (no-climate change)		% variation climate change scenarios to reference in 2080			
	IPCC SRES	2080	% growth	HadCM3	CSIRO	CGCM2	NCAR-PCM
Cereal production (billion tons)	**A1**	488	59%	7%			
	B1	468	52%	5%	9%		
	A2	593	93%	5%	7%	5%	19%
	A2r	569	85%				
	B2	542	77%	7%	9%	9%	11%
Agricultural output (GDP) in billion US$ constant 1990)	**A1FI**			-4.9%			
	A2			-0.5%	0.5%	3.5%	22.7%
	A2r	131	66%	0.9%	5.2%		
	B2			1.9%	2.0%	11.5 %	17.0%
	B1			-0.9%	3.5%		

Source: Own elaboration, data from Fischer et al. (2002) and Tubiello and Fischer (2007).Note: EEU: Eastern Europe; FSU: Former Soviet Union

The next table (Table 9) shows the analysis performed by Tubiello and Fischer (2007) comparing in the socio-economic scenario A2r, changes in

Agricultural GDP under climate change to reference (without climate change) and comparing results under climate change scenarios mitigated and unmitigated.

Table 9: Impact of climate change mitigated and unmitigated by using different climate models

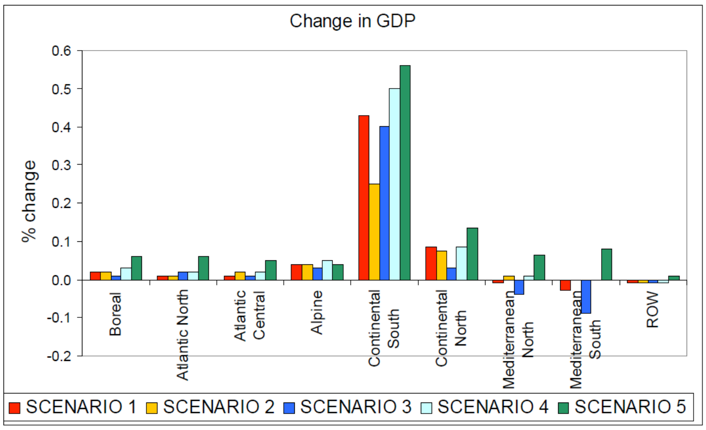
		2020				2050				2080			
		% variation climate change to reference		% variation climate change mitigated to unmitigated		% variation climate change to reference		% variation climate change mitigated to unmitigated		% variation climate change to reference		% variation climate change mitigated to unmitigated	
	IPCC SRES	HadCM3	CSIRO	HadCM3	CSIRO	HadCM3	CSIRO	HadCM3	CSIRO	HadCM3	CSIRO	HadCM3	CSIRO
Agricultural output (GDP) in billion US$ constant 1990)	**A2r**	1.4	1.5	-0.2	-0.2	1.1	3.1	0.4	-0.6	0.9	5.2	0.8	-1.6

Source: own elaboration, data from Tubiello and Fischer (2007)

All projections show positive changes in GDP compared to the reference scenario without climate change. However, the scenarios with mitigation policies indicate a less positive effect on agricultural GDP compared to the non-mitigated scenarios or even turn negative as all results from the CSIRO climate model show. So, again these are ambiguous results, depending much on the model applied. These results are aggregated results for Eastern Europe and Russia and could therefore largely vary for specific regions. In the respective studies refereed to as well as in the broader current literature base, however, very little can be found on the economic impacts of climate change on agriculture at a detailed regional level.

The only exception seems to be the PESETA study estimating economic impacts of climate change on agriculture in terms of agricultural GDP changes in 2080 compare to the baseline 1961-90 period, and distinguishing several agro-climatic zones. The estimated changes in GDP per region confirm the significant differences between Northern and Southern European countries. The effects on GDP are smaller than the productivity changes that usually occurs in general equilibrium simulations[8], due to the ability of the economy to substitute factors to accommodate changes. The effects on GDP are consistent with the physical effects of climate change (crop yield changes) that are positive in all regions except in the Mediterranean areas. The major increases are in the Continental South area, where the large productivity increases contribute more intensively to GDP increases because of the significant importance of the agricultural sector in the region (Parry *et al.* 2005).

Figure 8: Agriculture: GDP changes under climate change scenarios



Note: Scenarios 1 to 4 refer to the 2080s climate, compared to the 1961-1990 period: scenario 1 is A2 HadAM3h (3.9°C), scenario 2 is B2 HadAM3h (2.5°C), scenario 3 is A2 ECHAM4 (5.4 C), and scenario 4 is B2 ECHAM4 (4.1°C). Scenario 5 is the 2020s.

Source: JRC-IPTS Final report PESETA research project (2009)

According to the PESETA-Agriculture study mostly net benefits can be expected from climate changes in terms of agricultural output in Eastern Europe with the exception of the Mediterranean North zone, where the negative impacts from climate change seem to surpass the positive.

[8] The study uses the GTAP CGE model.

4 Conclusions

This literature review on the agricultural potentials in Eastern Europe has shown that there are good prospects for further production growth of major crops in the region. Medium term projections indicate the region's comparative advantage is in cereals, oilseeds and poultry meat as these show most significant growth figures up to 2020. Taking the long-term perspective, FAO projections indicate growth rates within the region fall short of world averages, but compared to present levels, estimated yield increases will result in significantly higher average production per hectare in 2050. Potential yield gains could be even higher if the socio-economic and policy environments in these countries further improve. In this respect it is important to mention that the current large differences between actual yields and attainable yields in Central and Eastern Europe implies a large need of public and private investments. A suitable policy framework is needed to attract private investment and to develop and implement technology. Therefore yield gains can not be achieved by technology alone, but also require complementary changes in policies and institutions.

Climate change through global warming is a global and long-term process that is expected to affect agricultural production seriously in the coming decades. The mechanisms and the extent to which this will have an impact is unclear. Currently available literature points at many uncertainties with respect to the extent climate variables may change, what the impact of temperature increases might be on greenhouse gases, and how CO_2 concentrations might impact on yields. Furthermore, socio-economic scenarios and adaptation capacities and/or policies play an important part in estimating the impacts of climate change on agricultural production, next to differences in climate areas and agro-ecological zones. Several studies combine climatic and biophysical models but only a few address the economic impacts of climate change in terms of future agricultural production and agricultural GDP, trade and prices under different socio-economic scenarios.

Eastern Europe is a wide geographical area and the impact of climate change on agriculture will probably be different for regions depending on current climate, soil and water conditions and availability and resources to face the change. The regional results of the PESETA study confirm the statement of Olesen and Bindi (2002) that northern countries will be positively affected by higher temperatures, while southern countries will be negatively impacted. High temperatures in northern countries in East Europe will extend the duration of the potential growing season impacting positively on the crop yields. In warmer, southern parts of Europe, increased temperatures imply less favourable conditions for crop growth and reduced yields. According to the PESETA study, in the northern parts of Eastern Europe (Continental North and South) yield increases are expected. The increase in the range of crops and longer growing season offers the opportunity for increased crop and livestock production. Water stress and risk of flooding in the Continental North zone may limit this potential. In the southern parts of Eastern Europe (Mediterranean North) net negative impacts are expected from a decline in the optimal farmer conditions, crop productivity decreases, droughts, pests and diseases. Again, these projections are subject to many uncertainties and based on several assumptions, which should be challenged by further and more comprehensive studies that are necessary to cover the regional, physical and economic impacts of climate change on agriculture in Eastern Europe.

Acronyms

AEZ	Agro-Ecological Zones
EEU	Eastern Europe
EU15	European Union 15
EU12	European Union 12
FAO	Food and Agricultural Organisation of the United Nations
FSU	Former Soviet Union
GHG	Green House Gases
IPCC	Intergovernmental Panel on Climate Change
JRC-IPTS	Joint Research Center-Institute for Prospective Technological Studies from the European Commission
MS	Moderately suitable (land)
ppm	parts per million
RF	Russian Federation
S	Suitable (land)
SRES	Special Report on Emission Scenarios
VS	Very Suitable (land)

References

Alcamo, J., Moreno, J. M., Nováky, B., Bindi, M., Corobov, R., Devoy, R. J. N., Giannakopoulos, C., Martin, E., Olesen, J. E., Shvidenko, A. 2007. "Europe", in: M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden & C.E. Hanson, (eds), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press, 541-580.

Bruinsma, J. 2009. The resource outlook to 2050: By how much do land, water and crop yields need to increase by 2050? Paper presented at the FAO expert meeting on How to feed the world in 2050, June 2009. Rome: FAO.

Deke, O., Hooss, K. G., Karsten, C., Klepper, G. and Springer K. 2001. *Economic Impact of Climate Change: Simulations with a Regionalized Climate-Economy Model.* Kiel Institute for the World Economy, Working paper 165.

FAO. 2006. *World Agriculture: towards 2030/2050*. Rome: FAO.

FAO. 2010. FAOSTAT data available from http://faostat.fao.org/site/377/DesktopDefault.aspx?PageID=377#ancor.

Fischer, G., Shah, M. and van Velthuizen, H. 2002. *Climate Change and Agricultural Vulnerability.* International Institute for Applied Systems Analysis (IIASA), Laxenberg. Special report.

Fischer, G. 2009. *World Food and Agriculture to 2030/50: How do climate change and bioenergy alter the long-term outlook for food, agriculture and resource availability?* Paper presented at the Expert Meeting on How to Feed the World in 2050, Food and Agriculture Organization of the United Nations, Economic and Social Development Department, 24-26 June, 2009.

Iglesias, A., Avis K. *et al.* 2007. *Adaptation to climate change in the agricultural sector.* Report for the European Commission DG AGRI.

IFPRI. 2009. *Climate Change: Impact on Agriculture and Costs of Adaptation.* Food Policy Report.

IPCC. 2007. Summary for Policymakers. In: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. and Miller, H. L. (eds). *Climate Change 2007: The Physical Science Basis.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Nowicki, P., van Meijl J.C. and Banse, M. 2010. *Scenar 2020-II. Update of scenario study on agriculture and the rural world.* Study for the European Commission DG-AGRI.

Olesen, J. E. and Bindi, M. 2002. Consequences of climate change for European agricultural productivity, land use and policy. *European Journal of Agronomy* **16**, 239-262.

OECD-FAO 2010. *Agricultural Outlook 2010-2019.* Paris: OECD.

Parry, M., Rosenzweig, C. *et al.* 2005. Climate change, global food supply and risk of hunger. *Philosophical transactions of the royal society,* **360**, 2125-2138.

Parry, M., Rosenzweig, C., Iglesias, A., Livermore, M. and Fischer, G. 2004. Effects of climate change on global food production under the SRES emissions and socieconomic scenarios. *Global Environmental Change,* **14,** 53-67.

PESETA-Agriculture. 2009. Climate change impacts in Europe-Final report of the PESETA project J.-C. Ciscar. IPTS: Sevilla.

Sadowski, M. 2008. *An approach to adaptation to climate change in Poland*. *Springer Science.*

Tubiello, F. N. and Fischer, G. 2007. Reducing climate change impacts on agriculture: Global and regional effects of mitigation, 2000-2080. *Technological Forecasting and Social Change,* **74,** 1030-56.

All the reports and papers produced by the Foresight Project on Global Food and Farming Futures may be downloaded from the Foresight website (http://www.bis.gov.uk/Foresight).

First published January 2011.

The Government Office for Science.

Any enquiries regarding this publication should be sent to:

Foresight, Government Office for Science
Department for Business, Innovation and Skills
1 Victoria Street
London SW1H 0ET

If you require this publication in an alternative format, email enquiries@bis.gsi.gov.uk, or call 020 7215 5000.

URN 11/596